METHOD AND APPARATUS FOR IMAGE SQUARENESS CORRECTION

BACKGROUND OF THE INVENTION

[0001]   Printing systems utilizing a Raster Output Scanning (ROS) device to form images on a photoreceptor surface are well known in the art. Conventionally, the ROS includes a diode or gas laser for generating a coherent beam of radiation, a modulator for modulating the laser output in accordance with an input video image signal, and a multifaceted polygon scanner for scanning the modulated laser beam output line by line across the surface of the photoreceptor to form the latent image. Also included in the ROS are various optical components to collimate, expand, focus, and align the modulated scanning beams. These optical components are fixedly mounted within a housing frame, which is positioned within a printer machine frame, so that the modulated and shaped scanning beams emerging from a window in the housing are directed perpendicular to the photoreceptor surface to form scan lines. The lines will be formed in parallel across the surface of the photoreceptor belt. The belt should be aligned so that these parallel lines are formed perpendicular to the direction of belt travel. It is difficult to achieve this perpendicularity, resulting in a condition referred to as "scan line skew" causing a squareness error, wherein the image effectively takes the form of a parallelogram. This condition will affect the images which are subsequently developed and transferred to output prints, the output prints exhibiting degradation of quality due to the skew effects.

[0002]   In the past, the ROS would be adjusted manually until the squareness error was eliminated, however, newer systems provide stepper motor driven ROS de-skew mechanisms. For example, in U.S. Patent Number 5,374,993 an adjustment example is provided that requires a multi-step procedure of printing a test pattern, determining a registration edge skew introduced by the paper feed path, determining a lead edge skew, subtracting the registration edge skew from the

lead edge skew to determine the scan line skew, loosening a clamp securing the ROS housing, determining the number of hex flat increments required to correct the scan line skew from a table, turning an adjustment screw by the indicated number of hex screw flat increments, and re-tightening the clamp securing the ROS housing.

SUMMARY OF THE INVENTION

[0003]   A method of correcting output image squareness in a laser printer system having a Raster Output Scanning (ROS) device with a pivotal mounting is provided. The method includes printing a test pattern that includes at least three markers such as crosshairs positioned in a predetermined geometric arrangement, measuring a plurality of distances between markers and calculating a skew angle based on the measured distances. In a preferred embodiment, the markers are printed in a rectangular arrangement and the skew angle is calculated using the Law of Cosines. The ROS device is then automatically rotated by an amount sufficient to correct the skew angle. The ROS rotation is performed automatically by an adjustment system connected to the ROS. The method optionally includes a scanner for scanning the test pattern image and making the measurements automatically via a program configured to analyze the scanned image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004]   FIGURE 1 is a representation of a ROS housing adjustably seated over a photoreceptor belt;

[0005]   FIGURE 2 shows a test pattern print output used to determine scan line skew;

[0006]   FIGURE 3 shows a skewed test print output and measurements;

[0007]   FIGURE 4 depicts correction of ROS skew during registration setup of a laser printer system; and

2

[0008]   FIGURE 5 shows an alternate skewed test print output and measurements.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0009]   Referring to FIGURE 1, there is shown an exemplary representation of a printer section **10** of a laser based printing system having an adjustable ROS housing **12** pivotally mounted at a pivot point **14** and having a ROS arm **16** and ROS ball **18** on the side opposite to the pivot point **14**. The ROS ball **18** docks in a notch **20** in a solid block **22**. A pair of flexible springs **24** and **26**, formed in the shape of a flat ribbon, are fixedly mounted to the solid block **22** and to a frame surface **28**. As viewed in FIGURE 1, only the edges of the springs **24** and **26** are visible. The springs **24** and **26** hold the block **22** against a cam **30** so that the cam **30** can rotate the ROS housing **12** about the pivot point **14**. The solid block **22**, flexible springs **24** and **26**, cam **30** and a stepper motor **32** form an adjustment system wherein the cam **30** is driven by the stepper motor **32** so that the process of rotating the ROS housing **12** can be automated electronically.

[0010]   It is to be appreciated that other arrangements and devices can be utilized for automating adjustment of the ROS housing **12** electronically, and that these other devices and arrangements fall within the scope of the present invention.

[0011]   As viewed from the perspective of FIGURE 1, ROS housing **12** is positioned above a photoreceptor belt **34**, and the ROS housing may include a laser, modulator, polygon scanner, and other optical elements required to focus and direct output beams which are in turn scanned across the moving photoreceptor belt **34**. Image lines are exposed at the photoreceptor belt **34** with each scan to create a latent electrostatographic image **36** of the document being imaged. The latent image **36** can then be developed and transferred to a copy sheet with the transferred image being fused. This process is well known to persons of average skill in the art. If the photoreceptor belt **34** is skewed in the process direction, however, the

3

scanned line **38** will not be perpendicular to the belt edges or parallel to the lead edge of the images in the process direction. The scan line **38** will vary from the desired perpendicular direction by a skew angle **40**, referred to hereinafter as angle ϕ. The resulting output prints will exhibit copy quality defects resulting from the scan line skew.

[0012]   According to the present invention, the ROS housing **12** is mounted within printer section **10** in such a way as to enable adjustment of the housing components to compensate for the housing-to-belt skew angle ϕ.

[0013]   As previously described, ROS housing **12** is pivotally mounted at a pivot point **14** and having a ROS arm **16** and ROS ball **18** on the side opposite to the pivot point **14**. The ROS ball **18** docks in a notch **20** in a solid block **22**. A pair of flexible springs **24** and **26**, formed in the shape of a flat ribbon, are fixedly mounted to the solid block **22** and to a frame surface **28**. The block **22** is, therefore, held in contact with the cam **30** which can rotate the ROS housing **12** about the pivot point **14** by moving the block **22** in the desired direction to reduce skew angle ϕ. For example, in one embodiment, the cam **30** can be configured so that rotating the cam in a clockwise direction from an initial position will cause ROS housing **12** to rotate in a counterclockwise direction, thereby numerically increasing skew angle ϕ, wherein a preferred value of zero is represented by a dashed line **42**. Similarly, rotating the cam in a counterclockwise direction from an initial position will cause ROS housing **12** to rotate in a clockwise direction, thereby numerically reducing skew angle ϕ.

[0014]   In prior art environments, the ROS would be manually adjusted until the squareness error, skew angle ϕ, was eliminated. In the present embodiment, however, with a stepper motor driven ROS de-skew mechanism, the adjustment of the ROS angle **44**, hereinafter referred to as ROS angle θ, is automated. A system and process is therefore described herein for determining the skew angle ϕ

4

utilizing measured linear distances, and using those measurements as input for adjusting the ROS angle (θ) **44** to a preferred value of 90 degrees by reducing the magnitude of skew angle ϕ to substantially zero. In the embodiment described herein, three linear distances are utilized, however, other embodiments may use as few as two linear distances.

[0015]   A first step in measuring skew angle ϕ is to print a test pattern of markers, such as cross hatches for example. FIGURE 2 shows a test pattern **46** suitable for use in the present embodiment. Cross hatches **48, 50, 52** and **54** are printed such that they form the four corners of a rectangle. Rather than measuring the skew angle ϕ, or the complementary ROS angle θ, directly, it is more convenient and accurate to measure the distances between three pairs of the cross hatches as illustrated. The measured distances are labeled a (**56**), b (**58**) and c (**60**) in FIGURE 2. Distance **56** represents a horizontal distance, distance **58** represents a vertical distance, and distance **60** represents a diagonal distance.

[0016]   Referring now to FIGURE 3 which shows an exemplary printed test pattern having a nonzero skew angle ϕ, and with continuing reference to FIGURES 1 and 2, a procedure of determining ROS angle θ and skew angle ϕ is now described. Since ROS skew does not affect the angle of the line connecting the leftmost two crosshairs **48, 52** (distance b), it follows that $\phi = \pi/2-\theta$. Using the Law of Cosines, θ can be solved for with

$$\theta = \cos^{-1}\left(\frac{a^2 + b^2 - c^2}{2ab}\right) \qquad (1)$$

and hence

$$\phi = \frac{\pi}{2} - \cos^{-1}\left(\frac{a^2 + b^2 - c^2}{2ab}\right) \qquad (2)$$

or

$$\phi = \sin^{-1}\left(\frac{a^2 + b^2 - c^2}{2ab}\right) \qquad (3)$$

5

thus providing the desired measurement of skew angle ϕ (**40**).

[0017]   The correction of ROS skew during registration setup of a laser printer system is depicted in FIGURE 4. A laser printer system **62**, having ROS housing **12** configured as shown in FIGURE 1, and having a user interface **64**, is shown. A user via user interface **64** has printer system **62** print a test pattern **46** as a printed output. After the test pattern is printed, the user measures the distances labeled a, b and c (**56, 58** and **60**) according to the pattern shown in FIGURE 3. The user then inputs the distances a, b and c (**66**) into the user interface **64**, and the printer system **62** then, using Equation 3 above, calculates skew angle ϕ (**40**). The printer system **62** then operates stepper motor **32** under control of a program configured to control the stepper motor in order to rotate the cam **30** in a direction and angular displacement sufficient to reduce the magnitude of skew angle ϕ to substantially zero. This requires advance knowledge of the relationship between the number of micro-steps of rotation of the stepper motor and the corresponding change in the ROS angle. For example, assume the relationship for a given system is a clockwise skew angle change of 2×10^{-5} degrees per micro-step of clockwise stepper motor rotation. If the measured skew angle ϕ is equal to 2×10^{-2} degrees (CCW), the stepper motor would need to rotate 1,000 micro-steps (CW). The exemplary relationship can be expressed as:

   # of micro-steps = # of micro-steps/change in skew angle * skew angle error.

This particular motor/skew angle relationship is meant to serve as an example only. Other position-control mechanisms may be substituted for the stepper motor used in this example.

[0018]   In an alternative embodiment, a scanner **68** is provided to scan the printed test pattern **46** as shown by the dashed lines. Instead of a user manually measuring the distances and entering measured a, b and c distances via the user interface **64**, the printed test pattern **46** is entered into the scanner **68** which scans the printed test pattern and inputs the scanned test pattern into printer **62** which is

6

configured with a program to automatically calculate distances a, b and c, and then to rotate the cam **30** in a direction and angular displacement sufficient to reduce the magnitude of skew angle ϕ to substantially zero.

[0019]   The procedure depicted in FIGURE 4 can eliminate skew error in a single step, however, the procedure may be repeated one or more times to confirm correct angular positioning of the ROS housing **12**. It is also to be appreciated that, in the above-described process and an alternative process described below, the method of measuring and correcting scan line skew is independent of any registration edge skew produced by the paper feed mechanism. In the past, such as in the aforementioned U.S. Patent Number 5,374,993, it was necessary to subtract the registration edge skew from a lead edge skew to arrive at the scan line skew.

[0020]   An exemplary test pattern measurement and calculation of skew angle ϕ is provided here to demonstrate the use of Equation 3:

     a = 8 in.,

     b = 6 in.,

     c = 9.95 in. and

     ϕ = 0.595 degrees.

[0021]   Another exemplary test pattern measurement and calculation of skew angle ϕ is provided here to demonstrate an adjustment in a direction opposite to that of the first example wherein the resultant angle is negative in value:

     a = 8 in.,

     b = 6 in.,

     c = 10.05 in. and

     ϕ = -0.598 degrees.

[0022]   After printer system **62** adjusts the angular position of the ROS housing **12** for either of the two examples above, the preferred results of a second test would yield:

7

a = 8 in.,

b = 6 in.,

c = 10 in. and

ϕ = 0 degrees.

[0023]   While the embodiment described above utilizes a test pattern **46** having four rectangularly positioned crosshatches, it is to be understood that other known predetermined geometric shapes may be used requiring as few as two distance measurements. For example, FIGURE 5 shows a test pattern **70** having three crosshatches **72, 74** and **76** printed in the arrangement of an isosceles triangle. In this exemplary case, any two of distances labeled a, b and c (**78, 80, 82**) are measured. These distances respectively represent the measured lengths of the base, left and right legs of the skewed isosceles triangle **70**. The scan line skew is given by any one of the following equations depending on the choice of distances measured:

$$\phi = \sin^{-1}\left[\left(\frac{b^2}{a^2} - 1\right)\left(\frac{1}{\cos 30°}\right)\right] \qquad (4)$$

$$\phi = \sin^{-1}\left[\left(1 - \frac{c^2}{a^2}\right)\left(\frac{1}{\cos 30°}\right)\right] \qquad (5)$$

$$\phi = \sin^{-1}\left[\left(\frac{b^2 - c^2}{b^2 + c^2}\right)\left(\frac{1}{\cos 30°}\right)\right] \qquad (6)$$

where ϕ represents skew angle **40** as shown.

[0024]   Exemplary test pattern measurements representing positive and negative values of skew angle ϕ are provided here to demonstrate the use of Equation 4:

a = 6 in.,

b = 6.0452 in.,

c = 5.9545 in.,

ϕ = 1 degree,

and

8

a = 6 in.,

b = 5.9545 in.,

c = 6.0452 in.,

ϕ = -1 degree,

where ϕ is calculated using any one of Equations 4, 5 or 6 utilizing the respective two of distances a, b and c.

[0025]   While the invention has been described with respect to specific embodiments by way of illustration, many modifications and changes will occur to those skilled in the art. It is therefore, to be understood that the appended claims are intended to cover all such modifications and changes which fall within the true spirit and scope of the invention.